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Effect of Cow Bone Ash Particle Size Distribution on the Mechanical Properties of Cow Bone Ash-Reinforced Polyester Composites

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Abstract
This research work was carried out to study the influence of cow bone ash particles in polyester matrix composites in order to improve the properties of polyester matrix and to provide alternative use of cow bone which constitute a challenge to the environment especially in developing countries. Cow bone was sourced from an abattoir, washed, sun dried for 4week and then carbonized. The bone ashes were further pulverized using the ball mill. Sieve analysis was carried out on the pulverized bone ash particles into particle sizes of 75µm, 106µm and 300µm. Composite materials were developed by casting into tensile, hardness and flexural tests samples using pre-determined proportions of 2, 4, 6, and 8 wt % of the cow bone ash. The samples after curing were striped from the moulds and were allowed to further cure at room temperature for 3 weeks before tensile, hardness and flexural tests were performed on them. The results shows that use of cow bone ash particles of 75,106 and 300 μm led to the enhancement of the mechanical properties of polyester matrix. The tensile result shows that sample reinforced with 4% of particle size 300µm gave the highest value of UTS, sample with 8% of particle size 300µm bone ash has the highest value of tensile modulus. Flexural strength were highly enhanced with 8% of particle size 75µm has the highest value of bending strength, this shows that fine particles lead to improved strength. The best result for hardness was obtained from 6wt% 106μm cow bone ash-reinforced sample with a value of 87.8HV compared to the unreinforced polyester matrix with a value of 81HV.
Keywords: polyester, composites, mechanical properties, cow bone ash.

1. Introduction

There has been a growing interest to use composite materials in structural applications ranging from aircraft, space structures to automotive and marine applications instead of conventional materials. This is because advanced composites exhibit desirable physical and chemical properties that include high specific stiffness and strength, dimensional stability, temperature and chemical resistance. Modern composite makes up of about 65 per cent of all the composites produced today and is used for boat hulls, surfboards, sporting goods, swimming pool linings, building panels and car bodies (Kalpakjian, 1995).

The use of by-products as reinforcement is a modern technology for producing relatively inexpensive materials of high strength from suitable homogeneous matrix bases (Anagbo et.al, 2009). These wastes include metallurgical slags, wastes from agricultural processes such as cocoa husk, rice paddy husk as fillers in conventional polymers, coconut husk filled polymer for activated carbon used in water treatment and other civil engineering applications, (Babatope, 2014).

A large number of waste materials have been studied as possible component of inorganic and organic polymer composites with specific characteristics and application. The composite materials developed on the basis of unsaturated polyester resins and gypsum-fiber filler show relatively good strength characteristics and can find application in the machine-building industry for the production of housings and other parts, replacing other materials with similar parameters, but of higher cost (**Koleva et al., 2011).**

Cow bones were used in this research, this material constitutes a waste of natural resources especially in developing countries. Cow bones which are obtainable from slaughtered cows in abattoirs are readily available in Nigeria and are usually burnt or sold to feed mill for the production of animal feeds. However, this by-product in some cases are left to waste but can be used as reinforcement in polymer to produce composite materials; this does not only reduce the cost of composite materials but also offers opportunity for utilization of waste materials thereby reducing environmental pollution (Medupin et al, 2003).

It is often convenient to stiffen or harden a material, commonly a polymer, by the incorporation of particulate inclusions (Christensen, 1979). This work was carried out to investigate the applicability of cow bone particles to reinforce polyester matrix and fibre for structural applications with suitable mechanical properties. The effect of particle size distribution on the mechanical properties of the polyester composites was explored.

2.0 Materials and Methods

The materials that were used for this research work are: unsaturated polyester resin, cow bone, methyl ethyl ketone peroxide (MEKP) used as the catalyst, cobalt 2% in solution used as the accelerator, polyvinyl acetate used as the mould releasing agent, and ethanol used as a cleaning agent.

2.1. Material Preparation.

The cow bone was procured from the abattoir, washed so as to remove the dirty particles that might have been stuck to the bone, and sun dried for 4 weeks after which it was carbonized and finally pulverized using Denver laboratory ball mill. The particles from the process were sieved with sieve shaker 16155 model into 75, 106, and 300μm sieve sizes.

2.2. Mould Production.

Tensile mould of gauge length 90 × 5 × 3mm of a dumb-bell shape and flexural mould of 150 × 50 × 3mm were used for the production of tensile and flexural samples, respectively, from where the hardness samples were obtained.

2.3. Production of Composites.

To develop the composites, 1.5 g each of catalyst and accelerator was added to 120 g of the polyester resin while cow bone ash particulates was varied in a pre-determined proportion of 2, 4, 6, and 8wt%. After proper stirring, the homogenous slurry is poured into the mould and allowed to be cured at room temperature before being stripped from the mould. Three (3) samples were produced for each mechanical property that was carried out from each proportion. The striped samples are left to be cured further at room temperature for 3 weeks before the mechanical tests were carried out.

2.4. Mechanical Testing and Structural Characterization of Cast Samples.

Following the moulding of the composites, samples were prepared for tensile, flexural, and hardness tests. Scanning electron microscope (SEM) was used to investigate the miscibility between the fibre and matrix at the fractured surfaces. These tests were carried out as follows.

(a)Determination of the Tensile Properties of theMaterials. Tensile tests was performed on INSTRON 1195 at a fixed crosshead speed of 10mmmin−1. Samples were prepared according to ASTM D412 (ASTM D412 1983), as the test is being carried out the computer generates the required data and graphs

(b) Determination of the Flexural Property of the Materials.

Flexural test was carried out by using Testometric Universal Testing Machine in accordance with ASTM D790. To carry out the test, the grip for the test was fixed on the machine, the sample that has been cut into the test piece dimensions of 150mm × 50mm × 3mm was hooked on the grip, and the test commenced. As the specimen is stretched, the computer generates the required data and graphs. The flexural test was performed at the speed of 100 mm/min.

(c) Determination of the Hardness Property of the Materials.

Hardness test was carried out in accordance with ISO R 868, using shore D. The test was carried out by impressing the sample with the tip of the indenter for five seconds before taken the readings from the calibrated scale. Ten readings were taking for each sample and the average value was used as the representative value for the mechanical tests carried out.

(d) SEM Observation.

Morphology of the composites was observed using Zeiss SEM: Zeiss Ultra Plus 55 FECSEM, Zeiss, Oberkochen, Germany. Before the examination, the samples were prepared by cutting them with bench vice and hacksaw followed by gluing on sample holder and finally coated with carbon using Carbon Coater: EMITECH K950X, EM Technologies, Kent, England.

3. Results and Discussions

3.1. Variation of Tensile Properties with Fibre Content.

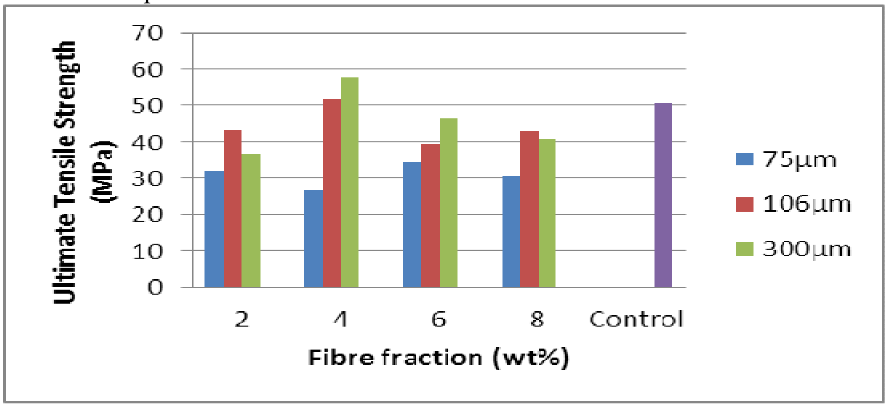


Figure 1: Ultimate tensile strength of cow bone ash-reinforced polyester composites.

Figure 1 shows the variation of Ultimate tensile strength of the samples with the fibre fraction. Ultimate tensile strength is the maximum stress that a material can withstand while being stretched or pulled before necking, The result shows that sample reinforced with 4% of particle size 300µm gave the highest value of UTS with 57.8244MPa, followed by 4% particle size of 106µm with 51.8572MPa compared with the control sample with 50.7MPa.

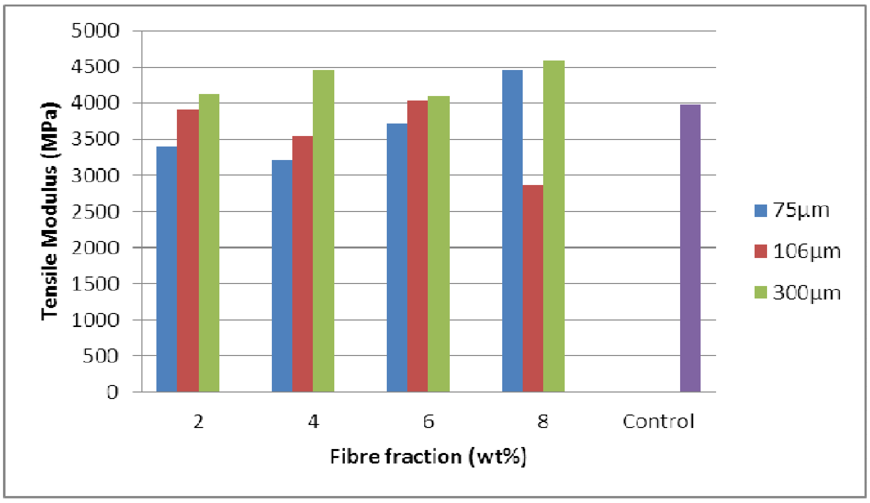


Figure 2: Tensile modulus of cow bone ash-reinforced polyester composites.

Figure 2 shows the variation of tensile modulus of the samples with fibre fraction of the bone ash reinforced composites. The tensile modulus is a measure of the stiffness of the material and is the rate of change of strain as a function of stress within an elastic limit.

Bone ash reinforced sample for 8% of particle size 300µm as the highest value with 4597.56MPa followed by 6% 300µm with 4454.38MPa, 8% 75µm with (4450.49MPa) compared with the control sample with 3966.15MPa

3.2. Variation of Flexural Properties with Fibre Content.

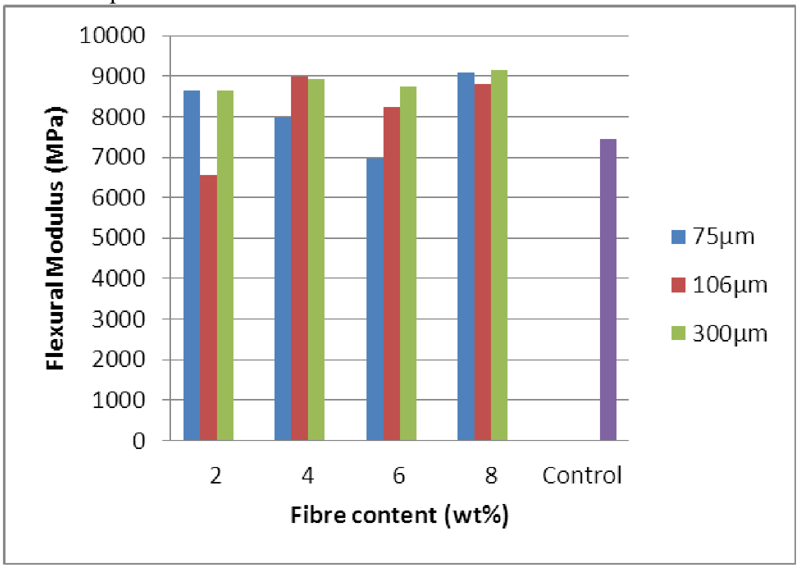


Figure 3: Flexural modulus of cow bone ash-reinforced polyester composites.

Figure 3 shows the variation of flexural modulus of the samples with fibre fraction of the bone ash reinforced composites. Bending modulus also known has flexural modulus of elasticity is the ratio of maximum fiber stress to maximum strain within elastic limit of stress-strain diagram obtained in flexure test. The result revealed that bone ash reinforced sample of 8% 300µm sample as the highest value of Bending Modulus (9137 $N.mm^2$), followed 8% 75µm bone ash reinforced sample with (9103 $N.mm^2$), compared with the control sample of 7451.8 $N.mm^2$.

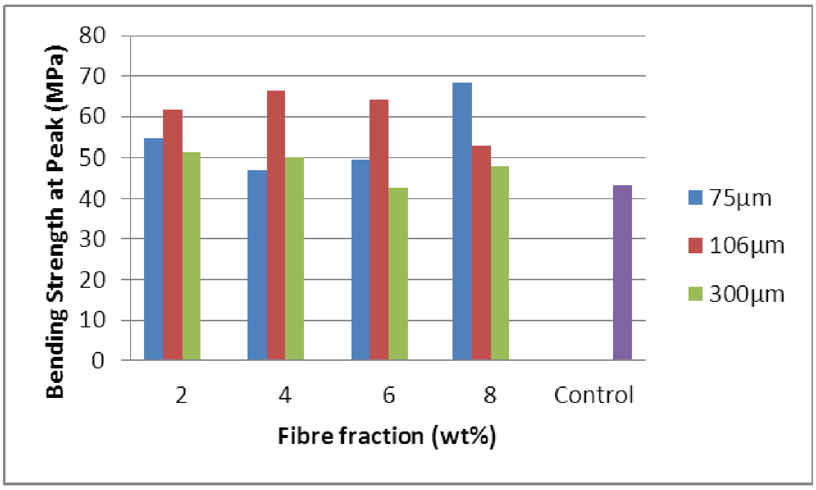


Figure 4: Bending strength at peak of cow bone ash-reinforced polyester composites.

Figure 4 shows the variation of bending strength at peak of the samples with volume fraction of the bone ash reinforced composites. Bending strength at peak is a material's ability to resist deformation under load. It represents the highest stress experienced within the material before rupture. From the result, bone ash reinforced sample 8% of particle size 75µm has the highest value of bending strength at peak (68.238MPa) followed by 106µm 4% bone ash reinforced sample with 66.231MPa compared with the control (43.254MPa).

3.3. Variation of Hardness Properties with Fibre Content.

Hardness property is a measure of the resistance of the materials to surface indentation and wear. Figure 5 shows the variation of the hardness values, it was noticed that the reinforcement led to the enhancement of the hardness property in all the samples. The best result was obtained for 6wt% from 106μm reinforced sample with a value of 87.8HV compared to the unreinforced polyester matrix with a value of 81HV. The result shows that 106μm particle reinforcement increases the hardness as the fibre content increases from 2 to 6wt% while the value drops at 8wt%.

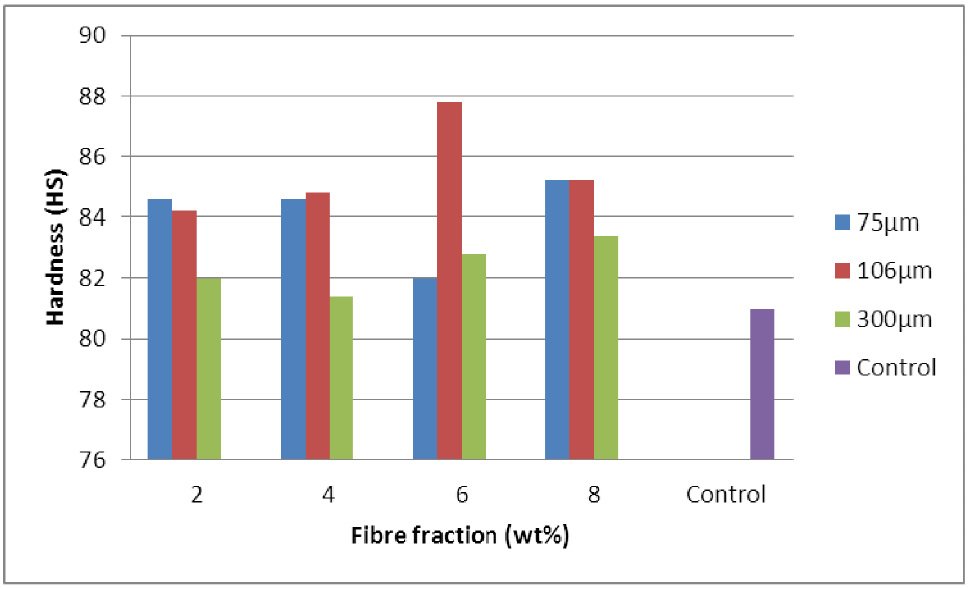
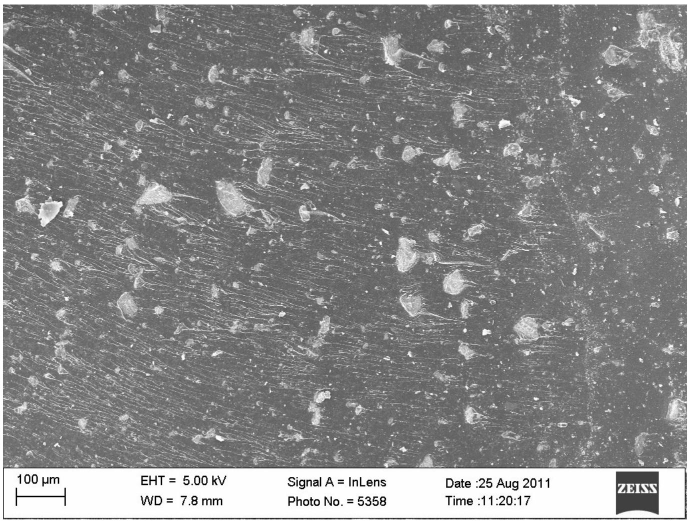
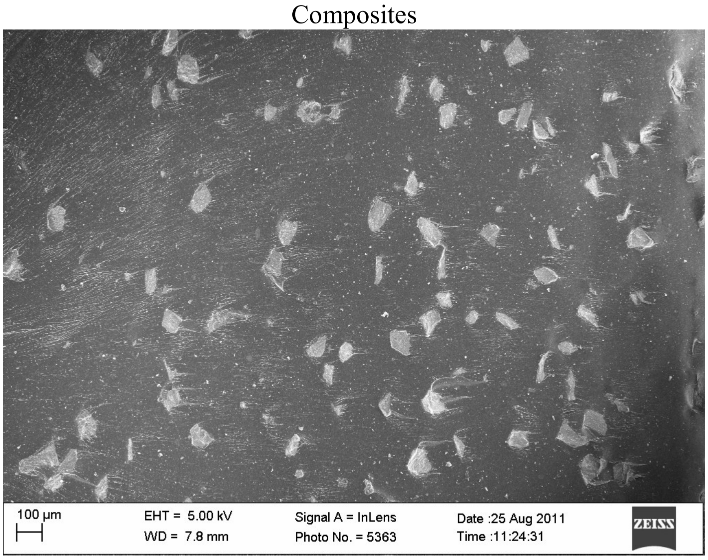


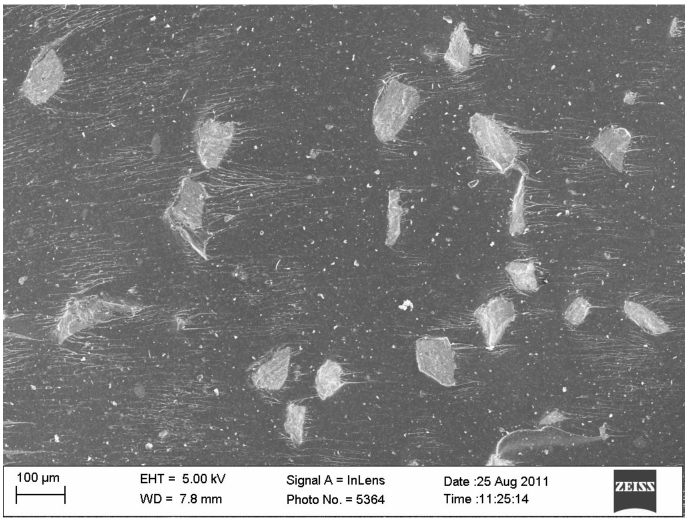
Figure 5: Hardness values of cow bone ash-reinforced polyester composites.



(a). SEM of Fractured surfaces of 8 wt % from 75 µm particle size Cow Bone Ash-Reinforced Polyester Composites



(b). SEM of Fractured surfaces of 8 wt % from 106 µm particle size Cow Bone Ash-Reinforced Polyester Composites



(c) SEM of Fractured surfaces of 8 wt % from 300 µm particle size Cow Bone and Cow Bone Ash- Reinforced Polyester Composites

Figure 6: (a)–(c) show the SEM micrograph of cow bone ash particulate reinforced polyester composites.
Plates (a- c) depict the SEM micrographs of cow bone ash particulates reinforced polyester composites. From the micrographs, it was observed that cow bone ash particles were well dispersed (white particle) in the polyester matrix (black surface). Figure 5(a) revealed more dispersal of the 75 μm particle compared to others. From Figures 5(a), 5(b), and 5(c), it was observed, that as the particle size increases, the number of particles that are present decreases. The micrographs revealed that there is proper bonding between the bone particles and the polyester matrix which was responsible for the good mechanical properties that was obtained from the mechanical tests results. The influence of the cow bone ash particles on the matrix was pronounced as this affects the dark coloration of the matrix by causing it to be more whitish (plates b, d, f). Carbonizing cow bones and introducing it into the polyester matrix has influenced the matrix structure, hence the properties. From the mechanical tests results stated above, it was revealed that better enhancement of the properties were achieved from the composites developed compared to the unreinforced polyester material due to proper dispersal of the particles in the polyester matrix.

4. Conclusion

The use of waste materials for production of composites has initiated the idea of using cow bone ash as reinforcement in polyester in order to develop polymer based composites for structural application in this research.

The following conclusions were drawn from the research work:

(i) The use of cow bone ash particles 75,106 and 300 μm led to the enhancement of the mechanical properties of polyester matrix.

(ii) The tensile result shows that sample reinforced with 4% of particle size 300µm gave the highest value of UTS with 57.8244MPa, bone ash reinforced sample for 8% of particle size 300µm has the highest value of tensile modulus with 4597.56MPa followed by 6% 300µm with 4454.38MPa while for hardness, the best result was obtained from 6wt% 106μm cow bone ash-reinforced sample with a value of 87.8HV compared to the unreinforced polyester matrix with a value of 81HV.

(iii) Flexural strength were highly enhanced 8% of particle size 75µm with the highest value of bending strength at peak (68.238MPa) followed by 106µm 4% bone ash reinforced sample with 66.231MPa compared with the control (43.254MPa). This shows that fine particles lead to improved strength. Fibre volume fraction of 8% particle size 300µm sample has the highest value of bending modulus (9137 MPa), followed 8% 75µm bone ash reinforced sample with (9103MPa).

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